Insider Trading and Real Activities Manipulation through Overproduction*

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Abstract

Corporate insiders, particularly managers, have access to their firms' private information as well as control over their firms' operational decisions. In this paper, we consider a setting where managers manipulate the firms' real activities in anticipation of subsequent insider trading opportunities. We find these managers choose production quantities that are strictly higher than the quantities absent insider trading. The increased production outputs lead to lower firm profits but higher consumer surplus. When we allow the managers to trade not only in their own firms but also in their rival firms' stocks, we find that the competition among insiders in the financial market drives down the expected insider trading profits and their incentives to distort production decisions. That is, the competition in the financial market softens the competition in the product market, indicating an implicit substitutable relation between the competitions in these two markets.

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1 Introduction

The political and academic debate surrounding insider trading is long-standing.[1] Under U.S. law, insider trading can be legal or illegal. While corporate insiders can trade their firms' stocks legally in compliance with government regulations and their firms' policies, the SEC refers to illegal insider trading as "*buying or selling a security, in breach of a fiduciary duty or other relationship of trust and confidence, while in possession of material, nonpublic information about the security.*"[2] Prior research on insider trading in finance, law, and economics often focuses on the legality of insider trading. In this paper, however, we intend to evaluate the "real" effect of insider trading - how insider trading opportunities affect the preceding operational decisions made by firm managers.

The "insiders" in the context of insider trading are often directors, officers, or other key employees of the firms involved. In fact, the majority of insiders have "inside" information about a firm precisely because they work at the firm. In addition to access to the firms' private information, these corporate insiders typically have control over the firms' operations. This paper seeks to address whether insiders use their control of the firms' real activities to benefit themselves through subsequent insider trading. Specifically, we examine the interaction of managers' production decisions and stock trading decisions, as well as the role of information and disclosure in this joint decision process.

It is not surprising that managers use accounting discretions to facilitate their profiting from insider trades. Numerous analytical studies (Kim and Verrecchia, 1994; Bushman and Indjejikian, 1995; Huddart et al., 2001; etc.) demonstrate disclosure strategies adopted by the managers to increase insider trading profits. Empirical evidences also confirm that managers use nonpublic information or biased disclosures for higher trading gains (Penman, 1982; Elliott, Morse and Richardson, 1984; Rogers and Stocken, 2005; Jagolinzer, 2009; etc.). However, managers can also manipulate real activities for the same purpose. Prior research shows that managers often use real activities opportunistically, such as to avoid reporting loss (Roydhowdhury 2006) or to meet earnings benchmark (Gunny 2005). In this paper, we

[1] For example, Manove (1989) shows that insider trading discourages investment and reduces efficiency. Ausubel (1990) and Fishman and Hagerty (1992) show that insider trading decreases the informativeness of a firm's stock price. Glosten (1989) and Leland (1992) show that insider trading decreases the firm's market liquidity. On the other hand, Manne (1966) argues that insider trading helps reduce agency problems by aligning the interests of the shareholders and managers of a firm. Bernhardt, Hollifield, and Hughson (1995) find that insider trading expedites the dissemination of private information and the price discovery process. Bhattacharya and Nicodano (2001) show that insider trading could improve risk-sharing among noise traders with stochastic liquidity needs. Laux (2010) demonstrates that investment decisions, specifically related to the abandonment of projects, can be improved when managers are allowed to time their trading activities based on insider information.

[2] See http://www.sec.gov/answers/insider.htm for more details.

show managers could manipulate real activities to maximize their personal trading profits.

Extending Kyle (1985), we consider a setting where an insider is the manager who makes operational decisions prior to trading in the firm's equity. We find introducing the possibility that the manager may trade in the firm's security creates incentives for increased production quantity, which is strictly higher than the output quantity absent insider trading. Increased quantity results because the manager's ex-ante expected trading profit increases in the variance of the monopoly firm's future profit, and this variance is amplified by higher production quantity. Higher production quantity thus leads to lower firm value but higher expected insider trading profit. When making production quantity decisions, the manager trades off the loss in his current stake in the firm and his personal gain from insider trading.

This result is largely consistent with the conventional wisdom that insider trading is detrimental to firm value. Specifically, we show that decreased firm value results from the upwardly distorted production quantity. However, the effect of the increased production quantity on social welfare may be quite different – as a higher output often leads to increased consumer surplus. From a regulatory perspective, this benefit should be balanced against the well-understood costs of information asymmetry in the capital markets on market liquidity.

We also find that information precision is inversely related to the manager's ex-ante expected trading profit. The more accurate the accounting signal, the lower the expected trading profit for the manager, and the lower the incentive for the manager to distort production quantity decision. Thus, the information precision is positively related to the expected final firm value.[3] Further, we find that expected firm value increases in the manager's current stake in the firm, as the manager's current stake in the firm also reduces his incentives to distort the quantity decision. These results hold in both monopoly and duopoly product markets.

When there are two firms competing in a Cournot market, we vary the insider trading regimes by allowing the managers to trade 1) only in their own firm's stock, or 2) in both their own and rival firm's stock. We find that the manager's insider trading profit is lower when he can trade in both his own and rival firms' stocks than when he trades in his own stocks only. That is, the competition in the financial market reduces the expected insider trading profits. The reduced expected insider trading profit also in turn reduces the manager's incentive to distort production quantity decisions, thus increasing the expected firm profit.

We contribute to the extant literature in three ways. First, we are the first to examine the effect of insider trading on managers' manipulation of real activities. While prior research

[3] This result is largely consistent with empirical evidence provided by prior studies such as Welker (1995), Lang and Lundholm (1996), Botosan (1997), Healy, Hutton and Palepu (1999), and Leuz and Verrecchia (2000).

focuses on managers using their informational advantages and/or disclosure strategies to increase personal trading gains, our results imply that managers can also exploit their control over their firms' operations for the same purpose. Further, we demonstrate the manager's actions affect not only his own firm, but also the consumer and the society at large.

Second, our results shed light on the interaction between financial markets and product markets. We find that the competition among insiders in the financial market drives down their informational advantage, a finding similar to that of Holden and Subrahmanyam (1992). Further, we find that competition in the financial market in turn dampens the over-competition in the product market, which implies an implicit substitutable relation between the competitions in these two markets. Thus, policy-makers should take into consideration the potential effect on one market while regulating the other.

Third, we show that the precision of accounting signals could reduce the expected insider trading profits, as well as the managers' incentives to distort production decisions. An accounting system that generates signals of high precision therefore mitigates agency problems, improves total shareholder value, and helps eliminate informational asymmetry between the corporate insiders and other traders in the financial market.

Our results are readily testable with empirical data. We predict that a firm whose CEO has higher percentage of stock ownership is more likely to engage in real activities manipulation, i.e., overproduction. However, the degree of competition within the industry in which the firm operates could mitigate the overproduction problem. The more competitive the industry, the less likely the participating firms overproduce, holding the CEOs' stock ownership equal. The precision of accounting information, which can be proxied by the volatility of earnings, should also be inversely related to the executives' manipulation of real activities.

Prior research on the relationship between insider trading and real activities is sparse. Similar to our paper, Jain and Mirman (2000, 2002) also combine a Kyle (1985) model with product market competition. However, their setting is quite different from ours. While we assume the noise in product market demand is an additive term and is realized at the end of the game, the noise term in Jain and Mirman (2000, 2002) is multiplicative and is learned by the manager before the production quantity decision. As a result, the second order condition is not always satisfied in their setting, and the normality condition of the Kyle model is violated in some circumstances.

Our paper also relates to prior studies of insider trading and accounting disclosure. Kim and Verrecchia (1994) find accounting disclosures could actually lead to increased information asymmetry and less liquidity in a Kyle setting. Bushman and Indjejikian (1995) also show that disclosure of private information can actually increase the managers' personal gain from insider trading by crowding out other informed traders from the financial market. Huddart et al. (2001) examine the case when insiders must publicly disclose their trades after these trades are completed. As a result, the insiders adopt a dissimulation strategy by adding noise in their orders. Gao and Liang (2013) evaluate a firm's optimal disclosure policy for the secondary stock market. Accounting disclosure reduces the informational asymmetry between the insiders and noise traders, but also leads to a less informative stock price and decreased investment efficiency. Baiman and Verrecchia (1995, 1996) consider principal-agent settings where the principal offers a best linear contract to the agent correctly extracting the agent's anticipated profits from subseqent insider trading. When insider trading profits are expected to be part of the manager's implicit compensation, disclosure leads to decreased insider trading profits and makes it more costly to hire and retain managers. None of these studies involve product market competition.

The rest of the paper is organized as follows: Section 2 introduces the basic model. Sections 3 presents the analyses and results for a monopoly setting, and Section 4 extends the analyses to a Cournot duopoly setting. Section 5 concludes the paper.

2 The Model

We consider an economy with one real good and two financial goods. The real good is manufactured by two firms, firm 1 and firm 2, that compete in a Cournot market. The two financial goods are these two firms' shares, which are traded in the stock market. The linear inverse demand function for the real good is $p = \widetilde{a} - q_1 - q_2$, where p is the unit price for the product; $\widetilde{a}$ is the intercept of market demand; and q_1 and q_2 are the output quantities produced and sold by each firm, respectively. The common market demand faced by the two firms is uncertain, with $\widetilde{a} \sim N(m_a, \Sigma_a)$, and is only realized after the production quantity decisions have been made.[4] Without loss of generality, we assume the firms' marginal cost is 0.

Each of the two firms is run by a risk-neutral manager, who is responsible for the firm's operations. These managers are the "insiders" of their firms, as they have access to their firms' information and control over their firms' operations. At the very beginning of the game, each manager privately receives a noisy signal about the market demand $\widetilde{a}$. The signal is $\widetilde{s}_i = \widetilde{a} + \widetilde{\theta}_i$, with $\widetilde{\theta} \sim N(0, \Sigma_\theta)$ and $i \in \{1, 2\}$. The precision of the signal s, $\frac{1}{\Sigma_\theta}$, represents the accuracy of accounting information.

The two firms operate under the same information disclosure regime. Either both firms

[4] Our assumption of common market demand simplifies the proofs but is not critical. When the two firms have firm-specific demand information, all the major results remain qualitatively the same.

must disclose their private signals, or neither firm discloses. If the managers disclose the private signals, the disclosure will be made to all participants in the product market as well as the financial market. If the managers do not disclose the private signals, then they cannot disclose to anybody.[5] We assume the disclosures are always truthful if they are required. Further, we assume all aspects of the model, including the precision of the accounting system, $\frac{1}{\Sigma_\theta}$, are common knowledge for everybody in the economy.

While we do not explicitly model the initial contracting between the original owners of the firm and the manager, we presume that, prior to our modelling frame, the managers were granted a certain amount of restricted stock from the firms at which they work. The restricted stock amounts to $0 < \omega < 1$ portion of the respective firm's total value. We assume that the manager's current stake in the firm is sufficiently small and does not affect the availability of the remaining shares being traded on the stock market.[6] For simplicity, we assume away any other compensation that managers may get from the firms.

The managers also have the chance to purchase more of the firms' shares. Following Kyle (1985), we consider three types of participants in the stock markets. The first type is the risk-neutral competitive market makers, who set the pricing rules and make zero trading profits. The second type is the noise traders who, for exogenous reasons, trade randomly. The third type is the insider-managers who make the quantity decisions for the respective firms, and observe the final market demand $\widetilde{a} = a$. The demand submitted by manager i is denoted $\widetilde{d_i}$, and the demand of the noisy trader is denoted $\widetilde{u} \sim N(0, \Sigma_u)$. The market maker observes the total order flow $\widetilde{D}_i$, but cannot distinguish d_i or u separately. She then sets the market clearing price for the firm's stock, P_i.

The timeline of the events is as follows.

1. The manager of firm i learns a private noisy signal of the market demand $\widetilde{s}_i$.

2. In a mandatory disclosure environment, each manager i discloses his received signal s_i. In a mandatory non-disclosure regime, the managers do not disclose any information.

3. Manager i makes production quantity decisions q_i, observable by all players.

4. The market demand a is realized, as well as the final firm value V_i, both privately observed by manager i.

5. Manager i submits his order d_i to the market maker i to purchase more shares.

[5] This assumption is largely consistent with the spirit of Regulation Fair Disclosure, which attempts to rule out the possibility of selective disclosure.

[6] Since the managers cannot trade the restricted stocks, they only want to maximize the long-term value of these stocks, not the short-term price fluctuations.

6. Market maker i receives a total order flow D_i and executes the trades.

In summary, the scenario described is a two-stage game involving quantity competition followed by a Kyle model. The solution concept we use is a perfect Bayesian equilibrium found through backward induction. The managers in our setting have two decision variables: the firms' production quantities and their own personal investments in the firms' shares. The market makers' problem is to set prices for the firms' stocks. We focus on linear strategies of the players, and evaluate the impact of subsequent insider trading on the product market competition by comparing the production quantities and the expected firm profits under different trading and disclosure regimes.

3 Monopoly with insider trading

We first examine a benchmark case involving a monopoly instead of a duopoly. The monopoly case shows how accounting information and subsequent insider trading could affect an manager's quantity decision, absent strategic competition in the product market. The timeline is the same as in the duopoly case. First the manager gets a private signal $\widetilde{s} = \widetilde{a} + \widetilde{\theta}$, based on which he updates his belief of the product market demand to $(a|s) \sim N\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a \Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$.

If insider trading is impossible, the manager would simply maximize his stake in the expected firm value. His objective function is

$$(1) \qquad \begin{aligned} & \max_q \omega\left(q(E\left[a|s\right]-q)\right) \\ = \ & \omega\left(q\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-q^2\right). \end{aligned}$$

The optimal production quantity chosen by the manager is $q^* = \frac{1}{2}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right)$. Since the market demand is uncertain, the firm value is thus

$$\widetilde{V}\left(s,\widetilde{a}\right) = \frac{1}{2}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right)\left(\widetilde{a}-\frac{1}{2}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right)\right).$$

It is easy to see that the firm value is normally distributed, with q affecting both the mean and the variance of the firm value, $\widetilde{V} \sim N\left(\frac{1}{4}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right)^2, \frac{1}{4}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right)^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$.

We then examine the scenario when insider trading is allowed. The manager chooses production quantity $\widehat{q}$ by maximizing his total payoff

$$(2) \qquad E\left[\omega\widetilde{V}\left(\widehat{q}\right)\right]+E\left[\Pi\left(\widehat{q}\right)\right].$$

Given $\widehat{q}$, the firm value is $\widetilde{V} \sim N\left(\widehat{q}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-\widehat{q}\right),\widehat{q}^2\frac{\Sigma_a+\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$.[7] The manager then observes the realized market demand $\widetilde{a}=a$, or $\widetilde{V}=V$. He and the noise traders both submit their demands, d and u, respectively, for the firm shares to the market maker. The manager does not observe the noise traders' demand $\widetilde{u}$. The total order flow received by the market maker is $\widetilde{D}=\widetilde{d}+\widetilde{u}$.The market maker sets the market clearing price by setting

$$P(D)=E\left[V|D=d+u\right]. \tag{3}$$

The manager decides his demand d by maximizing his personal trading profit

$$E\left[\left(V-P(D)\right)d|\widetilde{V}=V\right]. \tag{4}$$

As is standard in the Kyle model, we focus on linear strategies of the players. That is, the manager uses a linear strategy in determining his demand by setting

$$d(V)=\alpha+\beta\widetilde{V},$$

and the market maker uses a linear pricing rule

$$P\left(\widetilde{d}+\widetilde{u}\right)=\mu+\lambda\left(\widetilde{d}+\widetilde{u}\right). \tag{5}$$

Proposition 1. *In a monopoly product market with subsequent insider trading, there exists a unique linear equilibrium characterizing the strategies of the manager and the market maker as follows:*

$$\begin{aligned}
\alpha &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-\widehat{q}\right),\\
\beta &= \frac{\sqrt{\Sigma_u}}{\widehat{q}\sqrt{\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}},\\
\mu &= \widehat{q}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-\widehat{q}\right),\\
\lambda &= \frac{\widehat{q}}{2\sqrt{\Sigma_u}}\sqrt{\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}},
\end{aligned}$$

and

$$\widehat{q}=\frac{1}{4\omega}\left(2\omega\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}\right).$$

Proof. See appendix.

[7] Normality of the final firm value is a critical condition for obtaining the results of our paper. Bagnoli et al. (2001) and Noeldeke and Troeger (2001) show the necessary and sufficient conditions for the existence of a linear equilibrium in the Kyle model.

Proposition 1 presents a result similar to that of a one-period Kyle model, but incorporating a real production decision by the manager. Allowing insider trading distorts the manager's incentive when making the quantity decision for his firm. Since the mean and the variance of the final firm value are both functions of $\widehat{q}$, the quantity decision affects the manager's subsequent trading decision, as well as the market maker's pricing strategy.

When insider trading is banned, the production quantity is $\frac{1}{2}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right)$. When insider trading is allowed, the production quantity is $\frac{1}{4\omega}\left(2\omega\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}\right)$. It is obvious that the production quantity is always higher when insider trading is allowed. This result occurs because the manager's ex-ante trading profits, $E\left[\Pi\right]=\frac{\widehat{q}}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}$, increase in $\widehat{q}$. The manager thus has incentives to increase the production quantity beyond the profit-maximizing level.

One implication of Proposition 1 is the potentially improved consumer welfare as a result of insider trading. When the manager of the monopolistic firm has the opportunity to trade as an insider, the production quantity decision will be upwardly distorted. The consumers of the real good will therefore enjoy the lower selling price of the firm's products, hence higher consumer surplus.

Corollary 2. *In a monopoly product market with subsequent insider trading, the manager's ex-ante expected trading profit is*

$$E\left[\Pi\right]=m_a\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}+\frac{1}{2\omega}\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta},$$

which decreases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

The result presented in Corollary 2 is intuitive. The manager's ex-ante trading profit is a function of the variance of the firm's value. The higher the firm value's variance, the higher the informational advantage the insider has. Thus, the precision of the accounting signal affects the manager's expected trading profit in a negative way. The more precise the accounting signal is, the less trading profit the manager can expect.

Corollary 3. *In a monopoly product market with subsequent insider trading, the ex-ante expected firm profit is*

$$E\left[\widetilde{V}\right]=\frac{1}{16\omega^2}\left(4\omega^2m_a^2-\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right),$$

which increases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

When insider trading is impossible, the expected firm profit is $\frac{1}{4}\left(E\left[\frac{\Sigma_a \widetilde{s}+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right]\right)^2 = \frac{m_a^2}{4}$. It is obvious that the expected firm profit is lower when insider trading is allowed. The ex-ante expected firm profit with insider trading is lower than the monopoly profit due to the distorted quantity decision. Essentially, the manager trades off his current stake in the firm and his personal gain from insider trading when making the production quantity decision. Thus, the higher the manager's current stake in the firm, the less distortion in his quantity decision, and the higher the firm profit.

We can also see that the expected ex-ante firm profit increases in the accounting precision $\frac{1}{\Sigma_\theta}$. This result occurs because accounting precision reduces the manager's ex-ante trading profit and thus his incentives to distort the quantity decision. A very precise accounting signal would thus prevent managers from engaging in subsequent insider trading, and hence improve total firm value.

Note that since we assume the production quantity is observable by every player, the disclosure environment does not play a role in the monopoly case. After the manager receives a private signal s, the disclosure of this new information will only affect his quantity decision in the presence of a strategic rival in the product market competition. Once the production quantity is observed, all private information contained in s is also revealed.

4 Duopoly with insider trading

Next we examine the case when there are two firms competing in a Cournot product market. Having two firms brings significant impacts in both the product market and the financial market in our setting. In addition to the expected change in product quantity decisions, it also changes the behavior of managers when they make trading decisions.

4.1 When insider trading is not allowed

When insider trading is not allowed, the manager of each firm simply maximizes his own stake in the firm. In a mandatory disclosure environment, both managers have to disclose their private signals, s_1 and s_2. Thus they both get to use the two signals to update their belief about the market demand to $(a|s_1, s_2) \sim N\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Manager 1's problem is:

$$
\begin{aligned}
\text{(6)} \qquad & \max_{q_1} \omega \left(q_1 (E[a|s_1, s_2] - q_1 - q_2) \right) \\
= & \ \omega \left(q_1 \frac{\Sigma_\theta m_a + \Sigma_a (s_1 + s_2)}{2\Sigma_a + \Sigma_\theta} - q_1 (q_1 + q_2) \right)
\end{aligned}
$$

Manager 2's problem is symmetric. Solving for the production quantity as in a standard Cournot problem, we have

$$q_1^* = \frac{1}{3} \frac{\Sigma_\theta m_a + \Sigma_a (s_1 + s_2)}{2\Sigma_a + \Sigma_\theta}.$$

In a mandatory non-disclosure environment, the managers only observe their respective signals privately. Therefore, they only get to update their beliefs about the product market demand a once. For example, manager 1 believes that the market demand is $(a|s_1) \sim N\left(\frac{\Sigma_a s_1 + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}, \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}\right)$. Since manager 1 does not observe manager 2's signal s_2, he can only expect firm 2's manager to make production quantity decision based on the original information a.

Manager 1's problem is therefore:

$$
\begin{aligned}
\text{(7)} \qquad & \max_{q_1} \omega \left(q_1 (E[a|s_1] - q_1 - E[q_2]) \right) \\
= & \ \omega \left(q_1 \frac{\Sigma_a s_1 + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - q_1 (q_1 + E[q_2]) \right)
\end{aligned}
$$

Taking the first order condition with regard to q_1 and setting it to zero, we have

$$q_1 = \frac{1}{2} \frac{\Sigma_a s_1 + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \frac{1}{2} E[q_2]. \tag{8}$$

Since manager 1 doesn't know the signal received by manager 2, and manager 1 knows that manager 2 doesn't know manager 1's signal, he expects

$$E[q_2] = \frac{1}{2} m_a - \frac{1}{2} E[q_1]. \tag{9}$$

Applying symmetry and solving for the production quantities, we have

$$q_i = \frac{1}{3} \frac{(\Sigma_\theta - \Sigma_a) m_a + 2\Sigma_a s_i}{\Sigma_a + \Sigma_\theta}.$$

4.2 When managers only trade in their own firms' stocks

When insider trading is allowed, we first consider the case when each manager trades in his own firm's stock only. That is, the two firms compete in a duopolistic product market, but their managers still act as the monopolistic insiders of their respective stocks in the financial market. Thus, the second stage of the game (Kyle model) is similar to that of the monopoly setting, while the first stage of the game (Cournot) is different.

The manager i has two decision variables. First, he chooses production quantity $\widehat{q}_i$ by maximizing his total payoff

$$E\left[\omega\widetilde{V}_i\left(\widehat{q}_i\right)\right] + E\left[\Pi_i\left(\widehat{q}_i\right)\right]. \tag{10}$$

Second, he chooses his demand for his firm's share, d_i, by maximizing his total trading profit

$$E\left[\left(V_i - \widetilde{P}_i\left(\widetilde{D}_i\right)\right) d_i | \widetilde{V}_i = V_i\right]. \tag{11}$$

In the second stage of the game, the market maker determines the market clearing price for firm i's stock by setting

$$P_i\left(D_i\right) = E\left[V_i | D_i = d_i + u\right]. \tag{12}$$

Again, we focus on the players' linear strategies. Manager i's is

$$d_i\left(V_i\right) = \alpha_i + \beta_i \widetilde{V}_i,$$

and the market maker i's pricing rule is

$$P_i\left(\widetilde{d}_i + \widetilde{u}\right) = \mu_i + \lambda_i\left(\widetilde{d}_i + \widetilde{u}\right). \tag{13}$$

4.2.1 In a mandatory disclosure environment

In a mandatory disclosure regime, the firms must disclose s_1 and s_2 to the public. All players get to update their beliefs about the product market demand to $(a|s_1, s_2) \sim N\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Thus, given $\widehat{q}_1$ and $\widehat{q}_2$, firm 1's final value is $\widetilde{V}_1 \sim N\left(\widehat{q}_1\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}\right.\right.$

Proposition 4. *In a Cournot product market with mandatory disclosure, and subsequent insider trading where the managers only trade in their own firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager i and the market maker*

i, where $i, j \in \{1, 2\}$, as follows:

$$\alpha_i = -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta} - 2\widehat{q}\right),$$
$$\beta_i = \frac{\sqrt{\Sigma_u}}{\widehat{q}\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}},$$
$$\mu_i = \widehat{q}\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta} - 2\widehat{q}\right),$$
$$\lambda_i = \frac{\widehat{q}}{2\sqrt{\Sigma_u}}\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

and

$$\widehat{q}_i = \widehat{q}_j = \widehat{q} = \frac{1}{6\omega}\left(2\omega\frac{\Sigma_\theta m_a + \Sigma_a(s_i + s_j)}{2\Sigma_a + \Sigma_\theta} + \sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right).$$

Proof. See appendix.

As with the results in Proposition 1 about a quantity-setting manager in a monopoly, the results in Proposition 4 reflect the change in the nature of the product market structure. Comparing the manager's quantity decisions when insider trading is not possible, $q_i^* = \frac{1}{3}\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}$; and the managers' quantity decisions when insider trading is allowed, $\widehat{q}_i = \frac{1}{6\omega}\left(2\omega\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta} + \sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$; obviously we have $\widehat{q}_i > q_i^*$ again.

Similar to the monopoly case, we can expect improved consumer surplus as a result of the increased production quantities. Thus, the possibility exists that subsequent insider trading also improves consumer welfare in a duopoly market.

Corollary 5. *In a Cournot product market with mandatory disclosure, and subsequent insider trading where the managers only trade in their own firms' shares, manager's ex-ante trading profit is*

$$E[\Pi_i] = \frac{m_a}{6}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} + \frac{\Sigma_u}{12\omega}\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a + \Sigma_\theta},$$

which decreases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

This result is also similar to that of Corollary 2. The sum of the two manager's expected trading profit in a Cournot product market is only a $\frac{1}{3}$ of the manager's trading profit in a monopoly market, indicating that product market competition reduces insider trading profits. In a duopoly setting, the accounting precision also decreases the manager's ex-ante trading profit.

Corollary 6. *In a Cournot product market with mandatory disclosure, and subsequent insider trading where the managers only trade in their own firms' shares, each firm's ex-ante expected profit is*

$$E\left[\widetilde{V}_i\right] = \frac{1}{6\omega}\left(2\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\left(m_a - \left(\frac{1}{3\omega}\left(2\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\right)\right),$$

which increases in the manager's stake in the firm ω and accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

This result is very similar to that of Corollary 3, showing that the production quantities chosen by the managers in the Cournot firms are distorted due to the subsequent trading profits. The expected firm value when insider trading is not allowed is $\frac{1}{9}\left(E\left[\frac{\Sigma_\theta m_a + \Sigma_a(\widetilde{s}_i + \widetilde{s}_j)}{2\Sigma_a + \Sigma_\theta}\right]\right)^2 = \frac{m_a^2}{9}$,which is larger than the expected firm value when insider trading is allowed. The amount of distortion is however smaller compared to the monopoly case, because the manager's expected gain from the insider trading achieved through the quantity distortion is smaller. Further, we show that expected ex-ante firm value in the Cournot setting still increases in the manager's current stake in the firm and the accounting precision, both of which decrease the manager's incentives to distort the firm's quantity decision.

4.2.2 In a mandatory non-disclosure environment

In a non-disclosure regime, manager 1 does not see the signal received by manager 2. At the decision time for q_1, he can only update his belief about the product market demand to $(a|s_1) \sim N\left(\frac{\Sigma_a s_1 + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta}, \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}\right)$. However, after he observes his rival firm's production decision q_2, he could back out the signal s_2 and thus further update his belief to $(a|s_1, s_2) \sim N\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1 + s_2)}{2\Sigma_a + \Sigma_\theta}, \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}\right)$. The market makers also observe both q_1 and q_2 and are able to undertake the same updating of a.

Proposition 7. *In a Cournot product market with mandatory non-disclosure, and subsequent insider trading where the managers only trade in their own firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager i and the market* *maker i, where $i, j \in \{1, 2\}$, as follows:*

$$\alpha_i = -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}} \left(\frac{\Sigma_a s_i + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}_i - \widehat{q}_j \right),$$
$$\beta_i = \frac{\sqrt{\Sigma_u}}{\widehat{q}_i \sqrt{\frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}},$$
$$\mu_i = \widehat{q}_i \left(\frac{\Sigma_a s_i + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}_i - \widehat{q}_j \right),$$
$$\lambda_i = \frac{1}{2} \frac{\widehat{q}_i}{\sqrt{\Sigma_u}} \sqrt{\frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}},$$

and

$$\widehat{q}_i = \frac{1}{6\omega} \left(2\omega \left(2 \frac{\Sigma_a s_i + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - m_a \right) + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} \right).$$

Proof. See appendix.

The result presented in Proposition 7 is a combination of Kyle model and Darrough (1993). While Darrough (1993) models firm-specific market demand with different precision in the accounting signals, we assume common market demand and common accounting precision. The resulting strategies are however qualitatively the same.

In the non-disclosure regime, manager i's trading profit is

$$E[\Pi_i] = \frac{1}{6} \left(2 \frac{\Sigma_a s_i + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - m_a \right) \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} + \frac{\Sigma_u}{12\omega} \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}, \tag{14}$$

and the expected firm profit is

$$E\left[\widetilde{V}_i\right] = \frac{1}{6\omega} \left(2\omega \left(2 \frac{\Sigma_a s_i + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - m_a \right) + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} \right) \frac{\Sigma_a (s_i + 2s_j) + 3\Sigma_\theta m_a}{3(\Sigma_a + \Sigma_\theta)}. \tag{15}$$

Note that since s_i and s_j are noisy but unbiased signals of the market demand a, the expected production quantity $E[\widehat{q}_i]$ at time 0 (before the managers learn s_i and s_j) are the same in a mandatory disclosure regime and in a mandatory non-disclosure environment. Therefore, the ex-ante insider trading profit and firm value are also the same in the two disclosure environments.

Another interesting case of insider trading regimes is when the managers can trade only in his rival firms' stocks, instead of his own firms' stocks. This situation could happen when managers are forbidden from engaging in insider trading. Huang (2006) examines "substitute trading" when an manager trades in the stocks of a firm whose realized value is correlated with his own firm's. In our setting, since the two firms are symmetric and manager i is a complete insider of manager j's firm, the managers' payoffs would be exactly the same as when the managers trade only in their own firms' stocks. Thus, managers in our setting would have the same payoff regardless the legality of insider trading.

4.3 When managers trade in both their competitors' and own firms' stocks

Now we allow the managers to trade in both their rival firms' and own firms' stocks. This new assumption leads to duopolistic competition of the two managers both in the product market and in the financial market. The manager i still chooses production quantity $\widehat{q}_i$ by maximizing his total payoff

$$E\left[\omega \widetilde{V}_i\left(\widehat{q}_i\right)\right] + E\left[\Pi_i\left(\widehat{q}_i\right)\right].$$

He chooses his demand for his own firm i's share, d_{ii}, by maximizing his total trading profit in firm i's shares

$$E\left[\left(V_i - \widetilde{P}_i\left(\widetilde{D}_i\right)\right) d_{ii} | \widetilde{V}_i = V_i\right]; \tag{16}$$

and his demand for firm j's share, d_{ij}, by maximizing his total trading profit in firm j's shares

$$E\left[\left(E\left[V_j | V_i\right] - \widetilde{P}_j\left(\widetilde{D}_j\right)\right) d_{ij} | \widetilde{V}_i = V_i\right]. \tag{17}$$

The market maker for firm i's stock sets the market clearing price by setting

$$P_i\left(D_i\right) = E\left[V_i | D_i = d_{ii} + d_{ji} + u\right]. \tag{18}$$

Manager i's linear strategies are

$$d_{ii}\left(V_i\right) = \alpha_{ii} + \beta_{ii}\widetilde{V}_i \tag{19}$$

and

$$d_{ij}\left(V_i\right) = \alpha_{ij} + \beta_{ij}\widetilde{V}_i. \tag{20}$$

Lastly, the market maker i's linear pricing rule is

$$P_i\left(\widetilde{d}_{ii} + \widetilde{d}_{ji} + \widetilde{u}\right) = \mu_i + \lambda_i\left(\widetilde{d}_{ii} + \widetilde{d}_{ji} + \widetilde{u}\right). \tag{21}$$

4.3.1 In a mandatory disclosure environment

In a mandatory disclosure regime, all players update their beliefs about the product market demand to $(a|s_1,s_2)\sim N\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta},\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Thus, given $\widehat{q}_1$ and $\widehat{q}_2$, firm 1's value is $\widetilde{V}_1\sim N\left(\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right),\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$.

Proposition 8. *In a Cournot product market with mandatory disclosure, and subsequent insider trading where the managers trade in both their rival firms' and own firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager i and the market maker i, where $i,j\in\{1,2\}$, as follows:*

$$\begin{aligned}
\alpha_{ii}&=\alpha_{ji}=-\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}-2\widehat{q}\right),\\
\beta_{ii}&=\beta_{ji}=\frac{1}{\widehat{q}}\frac{\sqrt{\Sigma_u}}{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},\\
\mu_i&=\widehat{q}\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}-2\widehat{q}\right),\\
\lambda_i&=\frac{\widehat{q}}{3}\frac{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{\sqrt{\Sigma_u}}.
\end{aligned}$$

and

$$\widehat{q}_i=\frac{1}{9\omega}\left(3\omega\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right).$$

Proof. See appendix.

Compared to Proposition 4, Proposition 8 reflects the change in the players' strategies as a result of the change in the financial market in addition to the change in the product market. We know firm i's quantity decision is $\frac{1}{9\omega}\left(3\omega\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$ when insider trading is allowed and the managers trade in both their own and rival firms' stocks. Firm i's quantity decision is $\frac{1}{6\omega}\left(2\omega\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$ when insider trading is allowed and the managers only trade in their own firms' stocks. Firm i's quantity decision is $\frac{1}{3}\frac{\Sigma_\theta m_a+\Sigma_a(s_i+s_j)}{2\Sigma_a+\Sigma_\theta}$ when insider trading is not allowed. Obviously the quantity decision is lowest when insider trading is not allowed, and highest when insider trading is allowed and the managers only trade in their own firms' stocks.

Corollary 9. *In a Cournot product market with mandatory disclosure, and subsequent insider trading where the managers trade in both their rival firms' and own firms' shares,the manager's ex-ante trading profit is*

$$E[\Pi_i]=\frac{\Sigma_u}{27\omega}\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{m_a}{9}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

which decreases in accounting precision $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

Compared to the expected insider trading profit when managers only trade in their own firms' stocks, his trading profit when he can trade in both firms' stocks is much lower. This result is consistent with Holden and Subrahmanyam (1992) in that competition in the financial market reduces insider trading profit. Interestingly, the reduced insider trading profit also reduces the manager's incentive to distort the firm's operational decisions. Thus, when managers trade in both their own and rival firms' stocks, the production quantities are lower, and the expected firm profits are higher, than when managers only trade in their own firms' stocks.

Corollary 10. *In a Cournot product market with mandatory disclosure, and subsequent insider trading where the managers trade in both their rival firms' and own firms' shares, the firms earn an ex-ante expected profit*

$$E\left[\widetilde{V}_i\right] = \frac{1}{9\omega}\left(3\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\left(m_a - 2\left(\frac{1}{9\omega}\left(3\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\right)\right),$$

which increases in the manager's stake in the firm ω *and accounting precision* $\frac{1}{\Sigma_\theta}$.

Proof. See appendix.

Comparing the expected firm values in different insider trading regimes, we know the firm value is lowest when insider trading is allowed and the managers trade in only their own firms' stocks, and highest when insider trading is not possible. The expected ex-ante firm value when insider trading is allowed and the managers trade in both their own and rival firms' stocks is ranked in the middle.

4.3.2 In a mandatory non-disclosure environment

In a mandatory non-disclosure environment, when the managers are allowed to trade in both their own and rival firms' stocks, the strategies of the managers and market makers are characterized as follows.

Proposition 11. *In a Cournot product market with mandatory non disclosure, and subsequent insider trading where the managers trade in both their rival firms' and own firms' shares, there exists a unique linear equilibrium characterizing the strategies of the manager*

i and the market maker i, where $i, j \in \{1, 2\}$, as follows:

$$\begin{aligned}
\alpha_{ii} &= \alpha_{ji} = -\tfrac{1}{\sqrt{2\widehat{q}_i^2 - \widehat{q}_j^2}} \tfrac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}} \left(2\widehat{q}_i - \widehat{q}_j\right) \left(\tfrac{\Sigma_\theta m_a + \Sigma_a s_i}{\Sigma_a + \Sigma_\theta} - \widehat{q}_i - \widehat{q}_j\right), \\
\beta_{ii} &= \beta_{ji} = \tfrac{1}{\sqrt{2\widehat{q}_i^2 - \widehat{q}_j^2}} \tfrac{\sqrt{\Sigma_u}}{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}, \\
\mu_i &= \left(2\widehat{q}_i - \widehat{q}_j\right) \left(\tfrac{\Sigma_\theta m_a + \Sigma_a s_i}{\Sigma_a + \Sigma_\theta} - \widehat{q}_i - \widehat{q}_j\right), \\
\lambda_i &= \tfrac{\sqrt{2\widehat{q}_i^2 - \widehat{q}_j^2}}{3} \tfrac{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}{\sqrt{\Sigma_u}}.
\end{aligned}$$

and

$$\widehat{q}_i = \frac{1}{9\omega} \left(3\omega \left(2 \frac{\Sigma_\theta m_a + \Sigma_a s_i}{\Sigma_a + \Sigma_\theta} - m_a\right) + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right).$$

Proof. See appendix.

Again, since s_i and s_j are noisy but unbiased signals of the common market demand a, the expected production quantity $E\left[\widehat{q}_i\right]$ at time 0 is the same in a mandatory disclosure regime and in a mandatory non-disclosure environment.

5 Conclusions

In this paper, we intend to identify and evaluate a previously overlooked consequence of insider trading: real activities manipulation through overproduction. Specifically, we study insider trading in a setting where the manager of the firm also makes operating decisions in anticipation of subsequent insider trading opportunities. The effect of operating decisions on the variability of future firm value is the channel through which operating decisions also influence subsequent insider trading.

We find the production quantity with subsequent insider trading is strictly higher than quantity absent insider trading, leading to lower expected firm value but potentially higher consumer surplus. We also find that the competition among insiders in the financial market drives down the expected insider trading profits and results in less distorted production decisions, suggesting a substitutable relation between product market and financial market competition.

Our results have some important policy implications. First, allowing insider trading in our setting hurts shareholder interests, but benefits the consumers. Second, the product market and the financial market are interrelated. When one market is being regulated, the other market will be affected as well. For example, restricting some insiders from trading in a firm's stock softens the competition in the financial market and leads to higher expected insider trading profits, but intensifies the competition in the product market by giving the managers incentive to overproduce.

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Appendix

A Proof of Proposition 1:

We use backward induction to find the solution to the problem.

In the second stage, we know both the manager and the market maker use linear strategies. That is, $d\left(\widetilde{V}\right)=\alpha+\beta\widetilde{V}$ and $P\left(\widetilde{d}+\widetilde{u}\right)=\mu+\lambda\left(\widetilde{d}+\widetilde{u}\right)$. The manager determines his demand d for the firm's shares by maximizing his trading profit

$$\begin{aligned} & \max_d E\left[\left(\widetilde{V}-\mu-\lambda\left(\widetilde{d}+\widetilde{u}\right)\right)d|\widetilde{V}=V\right] \\ = & \left(V-\mu-\lambda d\right)d. \end{aligned} \tag{22}$$

Taking the first order condition w.r.t d and setting it equal to zero, we get

$$d=\frac{-\mu}{2\lambda}+\frac{1}{2\lambda}V. \tag{23}$$

Clearly, d is a linear function of V with $\alpha=\frac{-\mu}{2\lambda}$ and $\beta=\frac{1}{2\lambda}$.

Based on the manager's signal s, we know that the market demand is $(a|s)\sim N\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta},\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$. The corresponding final firm value is thus $\widetilde{V}\sim N\left(\widehat{q}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-\widehat{q}\right),\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right)$. Since $\widetilde{D}=\alpha+\beta\left(\widetilde{V}+\widetilde{u}\right)$, we know $\widetilde{D}$ is normally distributed with $\widetilde{D}\sim N\left(\alpha+\beta\widehat{q}\left(\frac{\Sigma_a s+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-\widehat{q}\right),\beta^2\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}+\Sigma_u\right)$. The market maker's market clearing condition is

$$\begin{aligned} p(D) &= E\left[\widetilde{V}|D\right] \\ &= E\left[\widetilde{V}|\alpha+\beta\widetilde{V}+u\right] \\ &= \mu+\lambda\left(d+u\right), \end{aligned} \tag{24}$$

indicating $\widetilde{D}$ and $\widetilde{V}$ have a var-cov matrix

$$\begin{bmatrix} \widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta} & \beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta} \\ \beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta} & \beta^2\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}+\Sigma_u \end{bmatrix}.$$

The market maker draws inference from $\widetilde{D}$ and updates her belief about $\widetilde{V}$ by setting

$$\lambda=\frac{\beta\widehat{q}^2\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}{\beta^2\widehat{q}^2\Sigma_a+\Sigma_u}, \tag{25}$$

and

$$\mu = \widehat{q}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) - \frac{\beta \widehat{q}^2 \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}{\beta^2 \widehat{q}^2 \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta} + \Sigma_u}\left(\alpha + \beta \widehat{q}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right)\right). \tag{26}$$

Solving for the unknowns, we have

$$\begin{aligned}
\alpha &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) \\
\beta &= \frac{\sqrt{\Sigma_u}}{\widehat{q}\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}, \\
\mu &= \widehat{q}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right), \\
\lambda &= \frac{1}{2}\frac{\widehat{q}}{\Sigma_u}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}.
\end{aligned}$$

The price for the firm's stock is therefore

$$p(D) = \frac{1}{2}\widehat{q}\left(\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) + (\widetilde{a} - \widehat{q}) + \frac{1}{\Sigma_u}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}\widetilde{u}\right). \tag{27}$$

The manager's demand for the firm's stock is

$$d = -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) + \frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}(\widetilde{a} - \widehat{q}). \tag{28}$$

The manager's trading profit is therefore

$$\begin{aligned}
& E\left[\left(\widetilde{V} - p\right) d\right] \\
(29) \quad = \; & E\left[\begin{array}{c}\left(\widehat{q}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) - \frac{1}{2}\widehat{q}\left(\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) + (\widetilde{a} - \widehat{q}) + \frac{1}{\Sigma_u}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}\widetilde{u}\right)\right) \\
\left(-\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}\left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q}\right) + \frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}(\widetilde{a} - \widehat{q})\right)\end{array}\right] \\
= \; & E\left[\frac{\sqrt{\Sigma_u}}{2\widehat{q}\sqrt{\frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}\left((\widehat{q}(\widetilde{a} - \widehat{q})) - \widehat{q}(a - \widehat{q})\right)^2\right].
\end{aligned}$$

Conditional on not yet knowing $\widetilde{a}$, the above trading profit is

$$\frac{\widehat{q}}{2}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}.$$

Now we consider the first stage of the game, when the manager makes the quantity decision for the firm. The manager's objective function is a combination of trading profits Π and firm value V. The manager's problem is:

$$\begin{aligned} & \max_{\widehat{q}} E[\Pi] + \omega [V] \\ = \; & \omega \widehat{q} \left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} - \widehat{q} \right) + \frac{\widehat{q}}{2}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} \end{aligned} \tag{30}$$

Taking the first order condition with regard to $\widehat{q}$ and setting it equal to zero, we have

$$\widehat{q} = \frac{2\omega \left(\frac{\Sigma_a s + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} \right) + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}}}{4\omega}.$$

B Proof of Corollary 2:

From the proof of Proposition 1, we know the manager's trading profit is

$$\begin{aligned} E\left[\left(\widetilde{V} - P \right) d \right] &= \frac{E[\widehat{q}]}{2}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} \\ &= E\left[\frac{\Sigma_a \widetilde{s} + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} \right] \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \frac{1}{2\omega} \Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}. \end{aligned}$$

Since the $E[\widetilde{s}] = m_a$, we know the $E\left[\frac{\Sigma_a \widetilde{s} + \Sigma_\theta m_a}{\Sigma_a + \Sigma_\theta} \right] = m_a$. Thus the above simplifies to

$$E[\Pi] = m_a \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \frac{1}{2\omega} \Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}.$$

Taking the first order derivative of $E[\Pi]$ with regard to Σ_θ, we have

$$\begin{aligned} & \frac{\partial}{\partial \Sigma_\theta} \left(m_a \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \frac{1}{2\omega} \Sigma_u \frac{\Sigma_a \Sigma_\theta}{\Sigma_a + \Sigma_\theta} \right) \\ = \; & \frac{1}{2\omega} \frac{\Sigma_a}{\Sigma_\theta (\Sigma_a + \Sigma_\theta)} \left(\sqrt{\Sigma_a \Sigma_u \frac{\Sigma_\theta}{\Sigma_a + \Sigma_\theta}} + \omega m_a \right) \sqrt{\Sigma_a \Sigma_u \frac{\Sigma_\theta}{\Sigma_a + \Sigma_\theta}} > 0. \end{aligned}$$

Thus $E[\Pi]$ increases in Σ_θ, or decreases in $\frac{1}{\Sigma_\theta}$.

C Proof of Corollary 3:

When insider trading is allowed, the expected firm profit is

$$\begin{aligned} E[V] &= E\left(E[\widehat{q}]\left(\widetilde{a}-E[\widehat{q}]\right)\right) \\ &= \frac{1}{16\omega^2}\left(4\omega^2\left(E\left[\frac{\Sigma_a\widetilde{s}+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}\right]\right)^2-\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right) \\ &= \frac{1}{16\omega^2}\left(4\omega^2 m_a^2-\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}\right). \end{aligned}$$

Examining the relation between expected firm profit and the manager's current stake in the firm,

$$\frac{\partial}{\partial\omega}\left(E[V]\right)=\frac{1}{8\omega^3}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{\Sigma_a+\Sigma_\theta}}>0,$$

indicating $E[V]$ increases in ω. Examining the relation between expected firm profit and Σ_θ,

$$\frac{\partial}{\partial\Sigma_\theta}\left(E[V]\right)=-\frac{1}{16\omega^2}\Sigma_a^2\frac{\Sigma_u}{\left(\Sigma_a+\Sigma_\theta\right)^2}<0,$$

indicating $E[V]$ decreases in Σ_θ, or increases in accounting precision $\frac{1}{\Sigma_\theta}$.

D Proof of Proposition 4:

Again, we use backward induction to find the solution.

In the second stage, manager 1 and the market maker 1 use linear strategies $d_1(V_1)=\alpha_1+\beta_1\widetilde{V}_1$ and $P_1\left(\widetilde{d}_1+\widetilde{u}\right)=\mu_1+\lambda_1\left(\widetilde{d}_1+\widetilde{u}\right)$. Manager i determines d_i by maximizing his trading profit

$$\begin{aligned} (31) \qquad & \max_{d_1} E\left[\left(\widetilde{V}_1-\mu_1-\lambda_1\left(\widetilde{d}_1+\widetilde{u}\right)\right)d_1|\widetilde{V}_1=V_1\right] \\ &= \left(V_1-\mu_1-\lambda_1 d_1\right)d_1. \end{aligned}$$

Taking the first order condition w.r.t d_1 and setting it equal to zero, we get

$$\alpha_1=\frac{-\mu_1}{2\lambda_1} \qquad (32)$$

and

$$\beta_1 = \frac{1}{2\lambda_1}. \tag{33}$$

Based on the two managers' signals s_1 and s_2, we know that the updated market demand is $(a|s_1, s_2) \sim N\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}, \frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. The corresponding final firm value is thus $\widetilde{V}_1 \sim N\left(\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right), \widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\right)$. Since $\widetilde{D}_1 = \alpha_1 + \beta_1\left(\widetilde{V}_1 + \widetilde{u}\right)$, we know $\widetilde{D}_1$ is normally distributed with $\widetilde{D}_1 \sim N\left(\alpha_1 + \beta_1\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right), \beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} + \Sigma_u\right)$. We also know that $\widetilde{V}_1$ and $\widetilde{D}_1$ are bivariate normal with

$$\begin{pmatrix} \widetilde{V}_1 \\ \widetilde{D}_1 \end{pmatrix} \sim N_2\left[\begin{array}{ccc} \widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right) & \widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} \\ \alpha_1 + \beta_1\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right) & , \; \beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} + \Sigma_u \end{array}\right].$$

Market maker 1 thus decides that

$$\lambda_1 = \frac{\beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} + \Sigma_u} \tag{34}$$

and

$$\begin{aligned} \mu_1 &= \widehat{q}_1\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right) \\ &\quad - \frac{\beta_1\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\beta_1^2\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} + \Sigma_u}\left(\alpha_1 + \beta_1\widehat{q}_1\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right)\right). \end{aligned} \tag{35}$$

Solving for the unknowns, we have

$$\begin{aligned} \alpha_1 &= -\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta^2}{2\Sigma_a\Sigma_\theta+\Sigma_\theta^2}}}\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right) \\ \beta_1 &= \frac{\sqrt{\Sigma_u}}{\widehat{q}_1\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}} \\ \mu_1 &= \widehat{q}_1\left(\frac{\Sigma_\theta m_a + \Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta} - \widehat{q}_1 - \widehat{q}_2\right) \\ \lambda_1 &= \frac{1}{2}\frac{\widehat{q}_1}{\Sigma_u}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}. \end{aligned}$$

The price for firm 1's share is therefore

$$
\begin{aligned}
P_1\left(D_1\right) &= \frac{1}{2}\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a\left(s_1+s_2\right)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right) \\
&\quad +\frac{1}{2}\widehat{q}_1\left(\widetilde{a}-\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{2\Sigma_u}\widehat{q}_1\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\widetilde{u}, \qquad (36)
\end{aligned}
$$

and manager 1's trading profit conditional on not knowing V_1 is

$$
\begin{aligned}
& E\left[\left(\widetilde{V}_1-\widetilde{P}_1\right)d_1\right] \qquad (37)\\
= & \frac{\widehat{q}_1}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}.
\end{aligned}
$$

In the first stage, manager 1 decides his production quantity $\widehat{q}_1$ by maximizing his total payoff. His problem is:

$$
\begin{aligned}
& \max_{\widehat{q}_1}\omega E\left[\widetilde{V}_1\right]+E\left[\Pi_1\right] \\
= & \ \omega\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a\left(s_1+s_2\right)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right)+\frac{\widehat{q}_1}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}} \qquad (38)
\end{aligned}
$$

Taking the first order condition with regard to $\widehat{q}_1$ and setting it equal to zero, we have

$$
\widehat{q}_1=\frac{2\omega\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_2\right)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{4\omega}.
$$

The problem facing manager 2 and market maker 2 is identical. Applying symmetry, we have

$$
\widehat{q}_1=\widehat{q}_2=\frac{1}{6\omega}\left(2\omega\frac{\Sigma_\theta m_a+\Sigma_a\left(s_1+s_2\right)}{2\Sigma_a+\Sigma_\theta}+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right).
$$

E Proof of Corollary 5:

Substituting the solutions from Proposition 4, we know the manager i's expected trading profit $E\left[\Pi_i\right]$ is

$$E\left[\left(\widetilde{V}_1-\widetilde{P}_1\right)d_1\right]=\frac{E\left[\widehat{q}_i\right]}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$$

$$=\frac{\Sigma_u}{12\omega}\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{1}{6}E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$$

$$=\frac{\Sigma_u}{12\omega}\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\frac{m_a}{6}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}. \tag{39}$$

Taking the first order derivative of $E\left[\Pi_i\right]$ with regard to Σ_θ, we have

$$\frac{\partial}{\partial\Sigma_\theta}E\left[\Pi_i\right]$$

$$=\frac{1}{6\omega}\frac{\Sigma_a}{\Sigma_\theta}\frac{\omega m_a+\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}>0.$$

F Proof of Corollary 6:

Given the solutions in Proposition 4, the expected firm value when insider trading is allowed is

$$\begin{aligned}
E\left[\widetilde{V}_i\right] &= E\left[E\left[\widehat{q}_i\right]\left(\widetilde{a}-E\left[\widehat{q}_i\right]-E\left[\widehat{q}_j\right]\right)\right]\\
&= \frac{1}{6\omega}\left(2\omega E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\\
&\quad \left(E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]-2\left(\frac{1}{6\omega}\left(2\omega E\left[\frac{\Sigma_\theta m_a+\Sigma_a\left(\widetilde{s}_i+\widetilde{s}_j\right)}{2\Sigma_a+\Sigma_\theta}\right]+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right)\\
&= \frac{1}{6\omega}\left(2\omega m_a+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\left(m_a-\left(\frac{1}{3\omega}\left(2\omega m_a+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)\right)\right).
\end{aligned}$$

Further, taking the first order derivative of $E\left[V_i\right]$ when insider trading is allowed, we have

$$\frac{\partial}{\partial\omega}E\left[V_i\right]$$

$$=\frac{2\Sigma_a\Sigma_u\Sigma_\theta+\left(2\omega\Sigma_a m_a+\omega\Sigma_\theta m_a\right)\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{18\omega^3\left(2\Sigma_a+\Sigma_\theta\right)}>0.$$

Again, we see the expected firm value increases in the manager's stake in the firm. Taking the first order derivative of $E[\Pi_i]$ with regard to Σ_θ, we have

$$\begin{aligned}&\frac{\partial}{\partial\Sigma_\theta}E[V_i]\\ =\;& -\frac{1}{18\omega^2}\frac{\Sigma_a}{\Sigma_\theta}\frac{\omega m_a+2\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}<0,\end{aligned}$$

the expected firm value increases in the accounting precision $\frac{1}{\Sigma_\theta}$.

G Proof of Proposition 7:

All market participants including the managers and the market makers observe the quantity decisions $\widehat{q}_1$ and $\widehat{q}_2$. They also all agree that the variance of firm 1's value $\widetilde{V}_1$ would be $\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}$. The solution to the second-stage game is thus the same as in Proposition 4. Manager 1's trading profit conditional on not knowing V_1 is also the same, $\frac{\widehat{q}_1}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}$.

In the first stage, manager 1 chooses his production quantity $\widehat{q}_1$ by maximizing his total payoff:

$$\begin{aligned}&\max_{\widehat{q}_1}\omega E\left[\widetilde{V}_1\right]+E[\Pi_1]\\ =\;&\omega\widehat{q}_1\left(\frac{\Sigma_a s_1+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-\widehat{q}_1-E[\widehat{q}_2]\right)+\frac{\widehat{q}_1}{2}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\end{aligned}\tag{40}$$

Taking the first order condition with regard to $\widehat{q}_1$, we have

$$\widehat{q}_1=\frac{2\omega\left(\frac{\Sigma_a s_1+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-E[\widehat{q}_2]\right)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{4\omega}.$$

Applying symmetry, we know

$$\widehat{q}_2=\frac{2\omega\left(\frac{\Sigma_a s_1+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-E[\widehat{q}_1]\right)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{4\omega}.$$

Since manager 1 does not know manager 2's signal s_2 yet at this stage of the game, he can only expect firm 2's manager to make production quantity decision based on the original information a. Thus we know

$$E[\widehat{q}_2]=\frac{2\omega(m_a-\widehat{q}_1)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{4\omega}$$

and

$$E\left[\widehat{q}_1\right]=\frac{2\omega\left(m_a-\widehat{q}_2\right)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{4\omega}.$$

Solving for unknowns, we have

$$\widehat{q}_1=\frac{1}{6\omega}\left(2\omega\left(2\frac{\Sigma_a s_1+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-m_a\right)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)$$

and

$$\widehat{q}_2=\frac{1}{6\omega}\left(2\omega\left(2\frac{\Sigma_a s_2+\Sigma_\theta m_a}{\Sigma_a+\Sigma_\theta}-m_a\right)+\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right).$$

H Proof of Proposition 8:

Let $d_{11}\left(\widetilde{V}_1\right)=\alpha_{11}+\beta_{11}\widetilde{V}_1$ be the demand manager 1 submits for firm 1's shares; and $d_{12}\left(\widetilde{V}_1\right)=\alpha_{12}+\beta_{12}\widetilde{V}_1$ be the demand manager 1 submits for firm 2's shares. Let $d_{22}\left(\widetilde{V}_2\right)=\alpha_{22}+\beta_{22}\widetilde{V}_2$ be the demand manager 2 submits for firm 2's shares, and $d_{21}\left(\widetilde{V}_2\right)=\alpha_{21}+\beta_{21}\widetilde{V}_2$ be the demand manager 2 submits for firm 1's shares. Market maker 1 sets the linear pricing strategy $p_1\left(\widetilde{d}_{11}+\widetilde{d}_{21}+\widetilde{u}_1\right)=\mu_1+\lambda_1\left(\widetilde{d}_{11}+\widetilde{d}_{21}+\widetilde{u}_1\right)$, and market maker 2 sets the strategy $p_2\left(\widetilde{d}_{22}+\widetilde{d}_{12}+\widetilde{u}_2\right)=\mu_2+\lambda_2\left(\widetilde{d}_{22}+\widetilde{d}_{12}+\widetilde{u}_2\right)$.

Manager 1 maximizes his trading profits from both firm 1's shares and firm 2's shares

$$E\left[\left(\widetilde{V}_1-\widetilde{p}_1\right)d_{11}|\widetilde{V}_1=V_1\right]+E\left[\left(E\left[\widetilde{V}_2\right]-\widetilde{p}_2\right)d_{12}|\widetilde{V}_1=V_1\right].$$

Since the production quantities are public information, and both managers observe the realized common market demand $\widetilde{a}=a$, the two managers know each other's firm values perfectly. That is, manager 1's objective function is

$$\begin{aligned}&\max_{d_{11},d_{12}}E\left[\left(\widetilde{V}_1-\widetilde{p}_1\right)d_{11}|\widetilde{V}_1=V_1\right]+E\left[\left(\widetilde{V}_2-\widetilde{p}_2\right)d_{12}|\widetilde{V}_2=V_2\right]\\=\;&\left(V_1-\mu_1-\lambda_1\left(d_{11}+d_{21}\right)\right)d_{11}+\left(V_2-\mu_2-\lambda_2\left(d_{12}+d_{22}\right)\right)d_{12}\end{aligned}$$

Taking the first order condition with regard to d_{11} and d_{12} we have

$$\widetilde{V}_1-\mu_1-2\lambda_1 d_{11}-\lambda_1 d_{21}=0,$$

and

$$\widetilde{V}_2-\mu_2-2\lambda_2 d_{12}-\lambda_2 d_{22}=0.$$

Manager 2's problem is symmetric to manager 1's. Thus we know

$$\begin{aligned}
d_{11} &= -\frac{1}{2\lambda_1}\left(-\widetilde{V}_1+\mu_1+\lambda_1 d_{21}\right),\\
d_{12} &= -\frac{1}{2\lambda_2}\left(-\widetilde{V}_2+\mu_2+\lambda_2 d_{22}\right),\\
d_{22} &= -\frac{1}{2\lambda_2}\left(-\widetilde{V}_2+\mu_2+\lambda_2 d_{12}\right),\\
d_{21} &= -\frac{1}{2\lambda_1}\left(-\widetilde{V}_1+\mu_1+\lambda_1 d_{11}\right),
\end{aligned}$$

which is equivalent to

$$\begin{array}{c}
\alpha_{11}=\alpha_{21}=\frac{-\mu_1}{3\lambda_1},\quad \beta_{11}=\beta_{21}=\frac{1}{3\lambda_1},\\
\alpha_{12}=\alpha_{22}=\frac{-\mu_2}{3\lambda_2},\quad \beta_{12}=\beta_{22}=\frac{1}{3\lambda_2}.
\end{array}$$

We know that market maker 1's strategy is

$$\begin{aligned}
P_1\left(\widetilde{D}_1\right) &= \mu_1+\lambda_1\widetilde{D}_1\\
&= \mu_1+\lambda_1\left(\alpha_{11}+\beta_{11}\widetilde{V}_1+\alpha_{21}+\beta_{21}\widetilde{V}_2+\widetilde{u}_1\right).
\end{aligned}$$

Again $\widetilde{V}_1$ and $\widetilde{D}_1$ are bivariate normally distributed with mean values $\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right)$ and $\alpha_{11}+\beta_{11}\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right)+\alpha_{21}+\beta_{21}\widehat{q}_2\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right)$, respectively. Their var-cov matrix is

$$\left[\begin{array}{cc}
\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \beta_{11}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}\\
\beta_{11}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta} & \left(\beta_{11}^2\widehat{q}_1^2+\beta_{21}^2\widehat{q}_2^2\right)\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u
\end{array}\right].$$

Thus, we have

$$\begin{aligned}
\lambda_1 &= \frac{\beta_{11}\widehat{q}_1^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\left(\beta_{11}^2\widehat{q}_1^2+\beta_{21}^2\widehat{q}_2^2\right)\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u},\\
\mu_1 &= E\left[\widetilde{V}_1\right]-\lambda_1 E\left[\widetilde{D}_1\right],\\
\lambda_2 &= \frac{\beta_{22}\widehat{q}_2^2\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}{\left(\beta_{22}\widehat{q}_2^2+\beta_{12}^2\widehat{q}_1^2\right)\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}+\Sigma_u},\\
\mu_2 &= E\left[\widetilde{V}_2\right]-\lambda_2 E\left[\widetilde{D}_2\right].
\end{aligned}$$

Solving for all the unknowns, we get

$$\alpha_{11} = -\frac{1}{\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(2\widehat{q}_1-\widehat{q}_2\right)\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right),$$

$$\alpha_{12} = -\frac{1}{\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(2\widehat{q}_1-\widehat{q}_1\right)\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_2-\widehat{q}_1\right),$$

$$\beta_{11} = \frac{1}{\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}\frac{\sqrt{\Sigma_u}}{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

$$\beta_{12} = \frac{1}{\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}\frac{\sqrt{\Sigma_u}}{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}},$$

$$\mu_1 = \left(2\widehat{q}_1-\widehat{q}_2\right)\left(\frac{\Sigma_\theta m_a+\Sigma_a(s_1+s_2)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right),$$

$$\lambda_1 = \frac{\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}{3}\frac{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{\sqrt{\Sigma_u}}.$$

For manager 2 and market maker 2, the solutions are symmetric.

Substituting the solutions into manager 1's total trading profit $E\left[\left(V_1-\mu_1-\lambda_1\left(d_{11}+d_{21}\right)\right)d_{11}\right]$ $+E\left[\left(V_2-\mu_2-\lambda_2\left(d_{12}+d_{22}\right)\right)d_{12}\right]$, conditional on manager 1 does not know the final value of a, we know his total expected trading profit is

$$\begin{aligned} & E\left[\frac{1}{3\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(\widetilde{V}_1-(2V_1-V_2)\right)^2\right] \\ & +E\left[\frac{1}{3\sqrt{2\widehat{q}_2^2-\widehat{q}1^2}}\frac{\sqrt{\Sigma_u}}{\sqrt{\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}\left(\widetilde{V}_1-(2V_2-V_1)\right)^2\right] \\ = & \frac{\widehat{q}_1^2\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}+\frac{\widehat{q}_2^2\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}. \end{aligned}$$

Manager 1 thus maximizes his total payoff by choosing quantity $\widehat{q}_1$:

$$\max_{\widehat{q}_1}\omega\left(\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a\left(s_1+s_2\right)}{2\Sigma_a+\Sigma_\theta}-\widehat{q}_1-\widehat{q}_2\right)\right)+\frac{\widehat{q}_1^2\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_1^2-\widehat{q}_2^2}}+\frac{\widehat{q}_2^2\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_2^2-\widehat{q}_1^2}}$$

Taking the first order condition with regard to $\widehat{q}_1$, we have

$$\omega\left(\frac{\Sigma_\theta m_a+\Sigma_a\left(s_1+s_2\right)}{2\Sigma_a+\Sigma_\theta}-2\widehat{q}_1-\widehat{q}_2\right)+\frac{1}{3}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\left(\frac{2\widehat{q}_1\left(\widehat{q}_1^2-\widehat{q}_2^2\right)}{\left(2\widehat{q}_1^2-\widehat{q}_2^2\right)^{\frac{3}{2}}}+\frac{\widehat{q}_1\widehat{q}_2^2}{\left(2\widehat{q}_2^2-\widehat{q}_1^2\right)^{\frac{3}{2}}}\right)=0.$$

Manager 2's problem is symmetric. Applying symmetry and solving for $\widehat{q}_1 = \widehat{q}_2$, we get

$$\widehat{q}_1 = \widehat{q}_2 = \frac{1}{9\omega}\left(3\omega\frac{\Sigma_\theta m_a + \Sigma_a (s_1 + s_2)}{2\Sigma_a + \Sigma_\theta} + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right).$$

I Proof of Corollary 9:

Substituting the solutions from Proposition 8, we know the manager i's expected trading profit $E[\Pi_i]$ is

$$\begin{aligned} E[\Pi_i] &= \frac{E[\widehat{q}]}{3}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} \\ &= \frac{\Sigma_u}{27\omega}\frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta} + \frac{1}{9}E\left[\frac{\Sigma_\theta m_a + \Sigma_a (\widetilde{s}_i + \widetilde{s}_j)}{2\Sigma_a + \Sigma_\theta}\right]\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} \\ &= \frac{\Sigma_u}{27\omega}\frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta} + \frac{m_a}{9}\sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} \qquad (41) \end{aligned}$$

Taking the first order derivative of $E[\Pi_i]$ with regard to Σ_θ, we have

$$\begin{aligned} &\frac{\partial}{\partial \Sigma_\theta} E[\Pi_i] \\ &= \frac{1}{9\omega}\frac{\Sigma_a}{\Sigma_\theta}\frac{\omega m_a + \sqrt{\Sigma_a \Sigma_u \frac{\Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}}{2\Sigma_a + \Sigma_\theta}\sqrt{\Sigma_a \Sigma_u \frac{\Sigma_\theta}{2\Sigma_a + \Sigma_\theta}} > 0. \end{aligned}$$

J Proof of Corollary 10:

The expected firm value when insider trading is allowed and the managers trade in both own and rival firms' stocks is

$$\begin{aligned} E\left[\widetilde{V}_i\right] &= E\left[E[\widehat{q}_i]\left(\widetilde{a} - E[\widehat{q}_i] - E[\widehat{q}_j]\right)\right] \\ &= \frac{1}{9\omega}\left(3\omega E\left[\frac{\Sigma_\theta m_a + \Sigma_a (s_i + s_j)}{2\Sigma_a + \Sigma_\theta}\right] + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right) \\ &\quad \left(E\left[\frac{\Sigma_\theta m_a + \Sigma_a (s_i + s_j)}{2\Sigma_a + \Sigma_\theta}\right] - 2\left(\frac{1}{9\omega}\left(3\omega E\left[\frac{\Sigma_\theta m_a + \Sigma_a (s_i + s_j)}{2\Sigma_a + \Sigma_\theta}\right] + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\right)\right) \\ &= \frac{1}{9\omega}\left(3\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\left(m_a - 2\left(\frac{1}{9\omega}\left(3\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right)\right)\right). \end{aligned}$$

Taking the first order derivative of $E[V_i]$ when insider trading is allowed, we have

$$\begin{aligned}&\frac{\partial}{\partial\omega}E[V_i]\\ =\ &\frac{\left(4\Sigma_a\Sigma_u\Sigma_\theta+(6\omega\Sigma_a+3\omega\Sigma_\theta)\,m_a\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\right)}{81\omega^3(2\Sigma_a+\Sigma_\theta)}>0.\end{aligned}$$

Again, we see the expected firm value increases in the manager's stake in the firm. Taking first order derivative of $E[V_i]$ with regard to Σ_θ, we have

$$\begin{aligned}&\frac{\partial}{\partial\Sigma_\theta}E[V_i]\\ =\ &-\frac{1}{81\omega^2}\frac{\Sigma_a}{\Sigma_\theta}\frac{3\omega m_a+4\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{2\Sigma_a+\Sigma_\theta}\sqrt{\Sigma_a\Sigma_u\frac{\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}<0,\end{aligned}$$

implying that $E[V_i]$ increases in accounting precision $\frac{1}{\Sigma_\theta}$.

K Proof of Proposition 11:

The solution to the second-stage game is thus the same as in Proposition 8.

In the first stage, manager 1 chooses his production quantity $\widehat{q}_1$ by maximizing his total payoff:

$$\max_{\widehat{q}_1}\omega\left(\widehat{q}_1\left(\frac{\Sigma_\theta m_a+\Sigma_a s_1}{\Sigma_a+\Sigma_\theta}-\widehat{q}_1-E[\widehat{q}_2]\right)\right)+\frac{\widehat{q}_1^2\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2\widehat{q}_1^2-E[\widehat{q}_2^2]}}+\frac{E[\widehat{q}_2^2]\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}}{3\sqrt{2E[\widehat{q}_2^2]-\widehat{q}_1^2}}$$

Taking the first order condition with regard to $\widehat{q}_1$, we have

$$\omega\left(\frac{\Sigma_\theta m_a+\Sigma_a s_1}{\Sigma_a+\Sigma_\theta}-2\widehat{q}_1-E\left[\widehat{q}_2^2\right]\right)+\frac{1}{3}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\left(\frac{2\widehat{q}_1\left(\widehat{q}_1^2-E[\widehat{q}_2^2]\right)}{\left(2\widehat{q}_1^2-E[\widehat{q}_2^2]\right)^{\frac{3}{2}}}+\frac{\widehat{q}_1E[\widehat{q}_2^2]}{\left(2E[\widehat{q}_2^2]-\widehat{q}_1^2\right)^{\frac{3}{2}}}\right)=0.$$

Since manager 1 does not know manager 2's signal s_2 yet at this stage of the game, he can only expect firm 2's manager to make production quantity decision based on the original information a. Thus

$$\omega\left(m_a-2E[\widehat{q}_1]-E[\widehat{q}_2]\right)+\frac{1}{3}\sqrt{\Sigma_u\frac{\Sigma_a\Sigma_\theta}{2\Sigma_a+\Sigma_\theta}}\left(\frac{2E[\widehat{q}_1]\left(E[\widehat{q}_1^2]-E[\widehat{q}_2^2]\right)}{\left(2E[\widehat{q}_1^2]-E[\widehat{q}_2^2]\right)^{\frac{3}{2}}}+\frac{\widehat{q}_1E[\widehat{q}_2^2]}{\left(2E[\widehat{q}_2^2]-E[\widehat{q}_1^2]\right)^{\frac{3}{2}}}\right)=0.$$

That is

$$E\left[\widehat{q}_1\right] = E\left[\widehat{q}_2\right] = \frac{1}{9\omega}\left(3\omega m_a + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right).$$

Applying symmetry and solving for unknowns, we have

$$\widehat{q}_1 = \frac{1}{9\omega}\left(3\omega\left(2\frac{\Sigma_\theta m_a + \Sigma_a s_1}{\Sigma_a + \Sigma_\theta} - m_a\right) + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right),$$

and

$$\widehat{q}_2 = \frac{1}{9\omega}\left(3\omega\left(2\frac{\Sigma_\theta m_a + \Sigma_a s_2}{\Sigma_a + \Sigma_\theta} - m_a\right) + \sqrt{\Sigma_u \frac{\Sigma_a \Sigma_\theta}{2\Sigma_a + \Sigma_\theta}}\right).$$